RESEARCH MEMORANDUM

A REVIEW OF THE PHYSICAL AND THERMODYNAMIC PROPERTIES
OF BORIC OXIDE

By Paul C. Setze

Lewis Flight Propulsion Laboratory
Cleveland, Ohio

NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

WASHINGTON
April 24, 1957
NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESEARCH MEMORANDUM

A REVIEW OF THE PHYSICAL AND THERMODYNAMIC PROPERTIES OF BORIC OXIDE

By Paul C. Setze

SUMMARY

A review of the current literature on the thermodynamic and physical properties of boric oxide (B$_2$O$_3$) was made. What were considered to be the most accurate data available on each of the following properties are presented in tabular and graphical form: specific heat, sensible enthalpy, total enthalpy, entropy, latent heat of vaporization, and vapor pressure for the crystal, liquid, and vapor states. Also given are data on specific gravity, surface tension, viscosity, and electrical resistivity. In addition, basic molecular and structural data are presented.

A discussion of each property is included, and reasons are stated for choosing one set of data in preference to another.

INTRODUCTION

In 1951 reference 1 was published giving tabulated data on the thermodynamic properties of a number of chemical elements and compounds. Among these compounds was boric oxide. Since that time new data on the properties of boric oxide have become available. This report reviews the published literature, presents what are believed to be the most accurate data now available on both the thermodynamic and physical properties of boric oxide, and extends the data where possible. This review is especially important in the light of some unreported experimental observations which make the extrapolation of existing data questionable. These cases will be discussed.

A search of the literature was made, and the data are presented in both graphical and tabular form. Each property
is briefly discussed and the reasons for choosing one set of data in preference to another indicated.

A list of the symbols used in this report is given in appendix A.

THERMODYNAMIC PROPERTIES

An extensive review of the literature on the thermodynamic properties of boric oxide is presented in reference 1, which provides tabulated data on specific heat, sensible enthalpy, total enthalpy, entropy, and equilibrium constants for the crystalline, liquid, and gaseous states. These data are being extensively used at the present time. However, more recent data on the vapor pressure, specific heat, enthalpy, and entropy of boric oxide make it desirable to recalculate the data of reference 1. This recalculation has been done, and a summary of the revised thermodynamic data is given in figure 1 and table I. A discussion of each of the separate thermodynamic properties follows.

Specific Heat

The specific heat data for boric oxide crystal, glass, and liquid are taken from a private communication received from the National Bureau of Standards. These values are based on experimental data which have a good order of accuracy. The glass and liquid data have been faired to a smooth curve in the range 900° to 1800° and extrapolated to 2500°. New values of the vapor specific heat were calculated using the method presented in reference 2. This method assumes the molecule to be a rigid harmonic oscillator, and the thermodynamic functions are calculated using the fundamental frequencies of oscillation given in reference 2. The equation used in calculating the specific heat is

\[ C_p^0 = 7.94372 + \sum C(v_1) \]  

(1)

where \( \sum C(v_1) \) is the sum of the vibrational contributions of a rigid harmonic oscillator, with frequencies \( v_1 \), to specific heat. This term was evaluated at each temperature from the tables of reference 3. The frequencies of the \( \text{B}_2\text{O}_3 \) molecule as calculated in reference 2 are presented in table II.
Sensible Enthalpy

The sensible enthalpies of the crystal, glass, and liquid were supplied by the National Bureau of Standards.

The sensible enthalpy of the vapor was calculated using the following equation, which was taken from reference 2:

\[ H_T^0 - H_L^0 = T \left[ 7.94872 + \sum H(v_i) \right] \]  \hspace{1cm} (2)

where \( \sum H(v_i) \) is the vibrational contribution to sensible enthalpy calculated from reference 3.

Total Enthalpy

The values for total enthalpy for the crystal, liquid, and vapor states were calculated using the sensible enthalpies from the preceding section and values of the standard-state total enthalpy at 0^oK chosen to be consistent with the tables of reference 1 and the vapor pressure data of reference 4.

Entropy

The crystal, glass, and liquid entropies are taken from the National Bureau of Standards data.

The vapor entropy was calculated using the following equation (ref. 2):

\[ S_T^0 = -2.3472 + 6.863476 \log M + 18.302602 \log T + \\
2.287825 \log(I_xI_yI_z10^{11}) - 4.57565 \log \sigma + \sum S(v_i) \]  \hspace{1cm} (3)

Latent Heat of Vaporization

The value for the latent heat of vaporization of boric oxide from the liquid was computed by taking the difference between the total enthalpy of the vapor and the total enthalpy of the liquid.

Vapor Pressure

Speiser, Naiditch, and Johnston (ref. 4) give experimentally determined values for the vapor pressure of boric oxide. Soulen, Sthapitanonda, and Margrave (ref. 5) verified these data within the accuracy of the method used, and Soulen indicated in reference 6 that extrapolation of the data of reference 4 was feasible.
The enthalpies for the liquid and vapor show that the latent heat of vaporization $\Delta H_v$ varies with temperature. The data presented in reference 4 do not take this change into account. Therefore, a new vapor-pressure-temperature relation was calculated from the following expression:

$$-RT \ln p_v = \Delta F^O_T = (H^O_T - TS^O_T)_v - (H^O_T - TS^O_T)_l$$

With a value for the vapor pressure at 1500°K (about the midpoint of the experimental data) from reference 4, a value of $(H^O_{1500})_v$ was calculated from equation (4). This calculation fixed the value of $(H^O)_v$ and, therefore, the remaining values of $(H^O)_l$. From these values, the vapor pressure was calculated from equation (4).

The results of this calculation (shown in fig. 1(e)) agree with the results given in reference 4 to within the experimental error.

Heat of Formation

The heats of formation of boric oxide vapor and crystal at 298.16°K and 0°K are calculated in appendix B.

Miscellaneous Thermodynamic Functions

The infrared and diffraction studies by Soulen (ref. 6) indicate that the structure of the B$_2$O$_3$ molecule is a symmetrical bipyramid as illustrated in figure 2. In this structure the three oxygen atoms form an equilateral triangle with one boron atom above and one below the plane of the triangle. Each boron atom is bonded to each of the oxygen atoms. Doubt exists as to the exact interatomic distances. Inasmuch as no recent accurate determinations have been made, the distances used in the calculations of reference 2 will be assumed to be correct until more data are available. These data are presented in table II.

PHYSICAL PROPERTIES

The physical properties of boric oxide are fairly well defined up to temperatures approaching 1800°K. Above this temperature materials problems make experimental determinations of physical properties very difficult if not impossible. Consequently, if data are needed at temperatures greater than 1800°K, extrapolation of the existing data is necessary, a procedure which leads to uncertainties in the value of the property.

The physical properties of boric oxide are presented in table III and figure 3. A discussion of each of the separate physical properties follows.

Specific Gravity

Reference 7 gives a plot of the coefficient of thermal expansion for B$_2$O$_3$ against temperature. Reference 8 gives a value of 1.85 for the
specific gravity of boric oxide at 298.16° K. Using the coefficient of expansion \( \alpha \) and the specific gravity at 298.16° K gives the following expression:

\[
\ln \frac{\rho_{298.16}}{\rho_T} = \int_{298.16}^{T} \alpha \, dT \tag{6}
\]

where

\[
\alpha = c_1 + c_2 T + c_3 T^2 \tag{7}
\]

The values of \( c_1, c_2, \) and \( c_3 \) were computed using the thermal expansion data of reference 7.

Substitution of equation (7) into equation (6) and integration gives

\[
\ln \frac{1.85}{\rho} = 15.90558 \times 10^{-4} T - 1.095738 \times 10^{-6} T^2 + 2.59248 \times 10^{-10} T^3 - 3.837 \times 10^{-1} \tag{8}
\]

as an expression for the specific gravity of \( \text{B}_2\text{O}_3 \) as a function of temperature.

The data of reference 7 (\( \alpha \) plotted against temperature) are given to about 1600° K; therefore extrapolation for equation (8) above this temperature would be beyond the range of the data. These data are plotted in figure 3(a).

Surface Tension

References 9 and 10 report consistent experimental determinations of the surface tension of boric oxide. The data of reference 9 were run up to 1700° K and give quite reproducible results. The equation that fits these data is

\[
\beta = 37.9 + 0.0354 T \tag{9}
\]

where \( T \) is in °K. The values calculated from this equation are plotted in figure 3(b).

From the experimental data it can be seen that the surface tension of boric oxide increases with temperature. This is not an uncommon occurrence when considering glasses. However, at some point the surface tension must begin to decrease with increasing temperature because at the critical temperature the liquid and vapor phases become indistinguishable and the surface tension approaches zero.
According to Freundlich (ref. 11) a positive temperature coefficient of surface tension can be explained by picturing a molecular species (different from the main body of the liquid) on the surface of the liquid that tends to lower the surface tension. As the temperature increases this species becomes more soluble in the body of the liquid, resulting in a net increase in surface tension. Because of this property, extrapolation of the surface tension data above 1700° K would present a great uncertainty.

Viscosity

References 12 through 14 give values of the viscosity of liquid boric oxide over a temperature range from 773° to 1373° K. The data are shown in figure 3(c). In general, all the data agree fairly well, but toward the lower temperatures some discrepancy exists. To arrive at some mean values for the viscosity, a curve was drawn through all the data. The values taken from this curve are presented in table III.

Electrical Resistivity

The electrical resistivity of boric oxide was taken from reference 15 and is presented in table III and figure 3(d). Also shown in the figure is a curve of some previously unpublished NACA data.

Miscellaneous Physical Properties

Solubility and index of refraction data were taken from reference 16 and are presented in the following table:

<table>
<thead>
<tr>
<th>Colorless glass or colorless white crystal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Index of refraction ........................ 1.464</td>
</tr>
<tr>
<td>Solubility, g/100 ml H₂O at</td>
</tr>
<tr>
<td>273.16° K ................................ 1.1</td>
</tr>
<tr>
<td>373.16° K ................................ 15.7</td>
</tr>
<tr>
<td>Soluble in acids and alcohols</td>
</tr>
</tbody>
</table>

CONCLUDING REMARKS

This report presents what are believed to be the most accurate data available on the properties of boric oxide. Whereas there may be some question as to the exactness of the data recommended, it is felt to be consistent.
The largest voids in the data exist when dealing with the species present in a vapor phase in equilibrium with B$_2$O$_3$ liquid. Experimental observations have been made that show increases in B$_2$O$_3$ vaporization rates due to water vapor in the surrounding atmosphere.

In a system containing B$_2$O$_3$ and elemental boron in the liquid state, B$_2$O$_3$ appears to be the predominant vapor species.

Dr. John L. Mergrave and his coworkers at the University of Wisconsin are presently involved in the most complete study of these phenomena. Their work is reported in references 5, 6, and 17.

In reference 17 the data indicate that the presence of small quantities of water vapor in the inert gas passing over liquid B$_2$O$_3$ greatly increased the vaporization rate of the oxide. The following reaction has been proposed to explain this phenomena:

$$H_2O(\text{vapor}) + B_2O_3(\text{liquid}) \rightarrow 2HBO_2(\text{vapor})$$

At about 1300° K with a water vapor partial pressure of 4 millimeters in nitrogen the B$_2$O$_3$ vaporization rate is increased about tenfold.

Lewis Flight Propulsion Laboratory
National Advisory Committee for Aeronautics
Cleveland, Ohio, November 8, 1956
**APPENDIX A**

**SYMBOLS**

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>$C_T^0$</td>
<td>standard-state specific heat at constant pressure, cal/(mole)(°K)</td>
</tr>
<tr>
<td>$C(v)$</td>
<td>vibrational specific heat function</td>
</tr>
<tr>
<td>$c_1,c_2,\ldots,c_3$</td>
<td>constants in power series</td>
</tr>
<tr>
<td>$F_T^0$</td>
<td>standard-state free energy, kcal/mole</td>
</tr>
<tr>
<td>$H_T^0$</td>
<td>standard-state total enthalpy, kcal/mole</td>
</tr>
<tr>
<td>$H_T^0 - H_0^0$</td>
<td>sensible enthalpy, kcal/mole</td>
</tr>
<tr>
<td>$H(v)$</td>
<td>vibrational enthalpy function</td>
</tr>
<tr>
<td>$\Delta H_f$</td>
<td>heat of formation, kcal/mole</td>
</tr>
<tr>
<td>$\Delta H_v$</td>
<td>latent heat of vaporization, kcal/mole</td>
</tr>
<tr>
<td>$I_x,I_y,I_z$</td>
<td>moments of inertia with respect to the x-, y-, and z-axes, (g)(cm²)</td>
</tr>
<tr>
<td>$M$</td>
<td>molecular weight, g/mole</td>
</tr>
<tr>
<td>$p$</td>
<td>pressure, atm</td>
</tr>
<tr>
<td>$R$</td>
<td>universal gas constant, 1.98718 cal/(mole)(°K)</td>
</tr>
<tr>
<td>$S_T^0$</td>
<td>standard-state entropy, cal/(mole)(°K)</td>
</tr>
<tr>
<td>$S(v)$</td>
<td>vibrational entropy function</td>
</tr>
<tr>
<td>$T$</td>
<td>absolute temperature, °K</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>volume coefficient of expansion, °K⁻¹</td>
</tr>
<tr>
<td>$\beta$</td>
<td>surface tension, dynes/cm</td>
</tr>
</tbody>
</table>
\( \rho \)  specific gravity
\( \sigma \)  symmetry number

**Subscripts:**

\( l \)  liquid
\( 0 \)  \( 0\,^\circ \) K
\( T \)  temperature
\( v \)  vapor

**Superscript:**

\( o \)  standard state (1 atm pressure)
APPENDIX B

CALCULATION OF THE HEAT OF FORMATION OF BORIC OXIDE

The heat of formation of $\text{B}_2\text{O}_3$ was calculated by the following procedure:

(1) $2\text{B}(\text{C}, 298.16) + 3/2 \text{O}_2(\text{V}, 298.16) \rightarrow \text{B}_2\text{O}_3(\text{C}, 298.16)$ \hspace{1cm} $\Delta H_1 = -305.35$ kcal (ref. 4)

(2) $\text{B}_2\text{O}_3(\text{C}, 298.16) \rightarrow \text{B}_2\text{O}_3(\text{C}, 0)$ \hspace{1cm} $\Delta H_2 = -2.241$ kcal (ref. 1)

(3) $\text{B}_2\text{O}_3(\text{C}, 0) \rightarrow \text{B}_2\text{O}_3(\text{V}, 0)$ \hspace{1cm} $\Delta H_3 = 88.6224$ kcal (table I)

(4) $\text{B}_2\text{O}_3(\text{V}, 0) \rightarrow \text{B}_2\text{O}_3(\text{V}, 298.16)$ \hspace{1cm} $\Delta H_4 = 2.9737$ kcal (table I)

(5) $2\text{B}(\text{C}, 298.16) + 3/2 \text{O}_2(\text{V}, 298.16) \rightarrow \text{B}_2\text{O}_3(\text{V}, 298.16)$ \hspace{1cm} $\Delta H_5 = \Delta H_1 + \Delta H_2 + \Delta H_3 + \Delta H_4$
\hspace{1cm} $\Delta H_5 = -214.9949$ kcal

(6) $2\text{B}(\text{C}, 0) \rightarrow 2\text{B}(\text{C}, 298.16)$ \hspace{1cm} $\Delta H_6 = 0.588$ kcal (ref. 20)

(7) $3/2 \text{O}_2(\text{V}, 0) \rightarrow 3/2 \text{O}_2(\text{V}, 298.16)$ \hspace{1cm} $\Delta H_7 = 3.105$ kcal (ref. 21)

(8) $2\text{B}(\text{C}, 0) + 3/2 \text{O}_2(\text{V}, 0) \rightarrow \text{B}_2\text{O}_3(\text{C}, 0)$ \hspace{1cm} $\Delta H_8 = \Delta H_1 + \Delta H_2 + \Delta H_6 + \Delta H_7$
\hspace{1cm} $\Delta H_8 = -303.8980$ kcal

(9) $2\text{B}(\text{C}, 0) + 3/2 \text{O}_2(\text{V}, 0) \rightarrow \text{B}_2\text{O}_3(\text{V}, 0)$ \hspace{1cm} $\Delta H_9 = \Delta H_5 + \Delta H_6 + \Delta H_7 - \Delta H_4$
\hspace{1cm} $\Delta H_9 = -214.2756$ kcal

Therefore,

$\Delta H_f(\text{B}_2\text{O}_3, \text{vapor}, 0^\circ \text{K}) = -214.2756$ kcal/mole

$\Delta H_f(\text{B}_2\text{O}_3, \text{vapor}, 298.16^\circ \text{K}) = -214.9949$ kcal/mole

$\Delta H_f(\text{B}_2\text{O}_3, \text{crystal}, 0^\circ \text{K}) = -303.898$ kcal/mole

$\Delta H_f(\text{B}_2\text{O}_3, \text{crystal}, 298.16^\circ \text{K}) = -305.35$ kcal/mole
REFERENCES


<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Crystal</th>
<th>Glass and Liquid</th>
<th>Vapor</th>
<th>Latent heat of sublimation (kJ/mol)</th>
<th>Vapor pressure (Pa)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Specific heat (J/g), molar heat capacity (J/mol K)</td>
<td>Total entropy (J/mol K)</td>
<td>Specific heat (J/g), molar heat capacity (J/mol K)</td>
<td>Total entropy (J/mol K)</td>
<td>Total entropy (J/mol K)</td>
</tr>
<tr>
<td>0</td>
<td>0.3852</td>
<td>0.3852</td>
<td>0.3852</td>
<td>0.3852</td>
<td>0.3852</td>
</tr>
<tr>
<td>20</td>
<td>2.164</td>
<td>2.164</td>
<td>2.164</td>
<td>2.164</td>
<td>2.164</td>
</tr>
<tr>
<td>50</td>
<td>5.955</td>
<td>5.955</td>
<td>5.955</td>
<td>5.955</td>
<td>5.955</td>
</tr>
<tr>
<td>100</td>
<td>11.89</td>
<td>11.89</td>
<td>11.89</td>
<td>11.89</td>
<td>11.89</td>
</tr>
<tr>
<td>150</td>
<td>18.84</td>
<td>18.84</td>
<td>18.84</td>
<td>18.84</td>
<td>18.84</td>
</tr>
<tr>
<td>200</td>
<td>26.76</td>
<td>26.76</td>
<td>26.76</td>
<td>26.76</td>
<td>26.76</td>
</tr>
<tr>
<td>250</td>
<td>34.70</td>
<td>34.70</td>
<td>34.70</td>
<td>34.70</td>
<td>34.70</td>
</tr>
<tr>
<td>300</td>
<td>42.66</td>
<td>42.66</td>
<td>42.66</td>
<td>42.66</td>
<td>42.66</td>
</tr>
<tr>
<td>350</td>
<td>50.63</td>
<td>50.63</td>
<td>50.63</td>
<td>50.63</td>
<td>50.63</td>
</tr>
<tr>
<td>400</td>
<td>58.61</td>
<td>58.61</td>
<td>58.61</td>
<td>58.61</td>
<td>58.61</td>
</tr>
</tbody>
</table>

*Glass below 725° K; liquid above 725° K.
*Relative to boric oxide crystal at 0° K.
*Extrapolated from 2500° to 3000° K.
TABLE II. - RECOMMENDED BASIC DATA ON THE BORIC OXIDE MOLECULE

<table>
<thead>
<tr>
<th>Ref.</th>
<th>Formula</th>
<th>Molecular weight</th>
<th>Interatomic distances, A:</th>
<th>Electronegativity:</th>
<th>Symmetry number</th>
<th>Force constant, dyne/cm:</th>
<th>Moment of inertia, g/cm²:</th>
<th>Calculated fundamental frequencies, cm⁻¹:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( \text{B}_2\text{O}_3 )</td>
<td>69.64</td>
<td>B-B: 1.72</td>
<td>B: 1.90</td>
<td>6</td>
<td>B-O: 6.809 \times 10^{-3}</td>
<td>( I_x ): 88.463 \times 10^{-40}</td>
<td>( v_1 ): 1363.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>B-O: 1.36</td>
<td>O: 3.45</td>
<td></td>
<td>O-O: 1.240 \times 10^{-5}</td>
<td>( I_y, I_z ): 70.805 \times 10^{-40}</td>
<td>( v_2, v_3 ): 1240.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0-0: 1.825</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>( v_4 ): 1525.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>( v_5 ): 466.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>( v_6, v_7 ): 1371.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>( v_8, v_9 ): 382.7</td>
</tr>
</tbody>
</table>
### TABLE III. - RECOMMENDED PHYSICAL PROPERTIES
OF BORIC OXIDE

<table>
<thead>
<tr>
<th>Temperature, °K</th>
<th>Specific gravity</th>
<th>Surface tension, dynes/cm</th>
<th>Viscosity, poises</th>
<th>Electrical resistivity, ohm/cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>298.16</td>
<td>1.85</td>
<td>48.5</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>400</td>
<td>1.69</td>
<td>52.1</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>500</td>
<td>1.56</td>
<td>55.6</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>600</td>
<td>1.47</td>
<td>59.1</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>700</td>
<td>1.59</td>
<td>62.7</td>
<td>&gt;1x10⁴</td>
<td>------</td>
</tr>
<tr>
<td>750</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>4.5x10⁵</td>
</tr>
<tr>
<td>800</td>
<td>1.34</td>
<td>66.2</td>
<td>7.0x10³</td>
<td>1.5x10⁵</td>
</tr>
<tr>
<td>900</td>
<td>1.30</td>
<td>69.8</td>
<td>1.6x10³</td>
<td>4.8x10⁴</td>
</tr>
<tr>
<td>1000</td>
<td>1.28</td>
<td>75.3</td>
<td>5.0x10²</td>
<td>2.2x10⁴</td>
</tr>
<tr>
<td>1100</td>
<td>1.26</td>
<td>76.8</td>
<td>2.0x10²</td>
<td>------</td>
</tr>
<tr>
<td>1200</td>
<td>1.25</td>
<td>80.4</td>
<td>9.7x10¹</td>
<td>------</td>
</tr>
<tr>
<td>1300</td>
<td>1.24</td>
<td>83.9</td>
<td>5.4x10¹</td>
<td>------</td>
</tr>
<tr>
<td>1400</td>
<td>1.23</td>
<td>87.5</td>
<td>3.3x10¹</td>
<td>------</td>
</tr>
<tr>
<td>1500</td>
<td>1.22</td>
<td>91.0</td>
<td>2.2x10¹</td>
<td>------</td>
</tr>
<tr>
<td>1600</td>
<td>1.218</td>
<td>94.5</td>
<td>1.6x10¹</td>
<td>------</td>
</tr>
<tr>
<td>1700</td>
<td>1.208</td>
<td>98.1</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>1800</td>
<td>1.191</td>
<td>101.6</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>1900</td>
<td>------</td>
<td>105.2</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>2000</td>
<td>------</td>
<td>106.7</td>
<td>------</td>
<td>------</td>
</tr>
</tbody>
</table>
Figure 1. - Recommended thermodynamic properties of boric oxide.
(b) Sensible enthalpy. To convert to total enthalpy, add 48.6839 kilocalories per mole to the glass or liquid sensible enthalpy and 139.297 kilocalories per mole to the vapor sensible enthalpy.

Figure 1. - Continued. Recommended thermodynamic properties of boric oxide.
Figure 1. - Continued. Recommended thermodynamic properties of boric oxide.
Molar latent heat of vaporization for boric oxide, kcal/mole

Figure 1. - Continued. Recommended thermodynamic properties of boric oxide.

(a) Latent heat of vaporization.
(a) Calculated vapor pressure.

Figure 1. - Concluded. Recommended thermodynamic properties of boric oxide.
Figure 2. - Model of boric oxide molecule.
Figure 3. - Recommended physical properties of boric oxide.
(b) Surface tension.

Figure 3. - Continued. Recommended physical properties of boric oxide.
Figure 3. - Continued. Recommended physical properties of boric oxide.
(d) Electrical resistivity.

Figure 3. Concluded. Recommended physical properties of boric oxide.